Monitoring Ionospheric Tota Electron Content Using the Global GPS Network

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We have developed the capability to monitor the global distribution of ionospheric total electron content (TEC) using dual-frequency observations from a worldwide network of Global Positioning System (GPS) ground receivers. Continuously operating, high-accuracy GPS receivers are currently installed at more than 60 sites around the world covering a wide latitude range (from Ny Alesund, Norway at 78°N to McMurdo, Antarctica at 77°S). By using spatial and temporal interpolation between the TEC measurements, combined with a simple ionospheric shell model, we are able to produce a global snapshot or map of vertical TEC every hour. A time-series of false-color maps can be combined to create an animation which shows the global evolution of ionospheric structure. We can also simultaneously estimate the instrumental biases in the GPS receivers and satellite transmitters, which must be determined in order to extract absolute TEC from the GPS line-of-sight observables.

The global mapping technique utilizes an ionospheric "shell model" approximation in which the ionization is assumed to lie in a thin spherical shell at a fixed height above the Earth, and the line-of-sight measurements are converted to equivalent vertical TEC using an elevation mapping function. Surface interpolation over a triangular grid on the shell is used to combine the individual measurements into a continuous regional or global map. The vertices of the grid are fixed in a solar-geomagnetic coordinate system (geomagnetic latitude and nearly Sun-fixed longitude) since the TEC distribution is slowly varying in that frame. A Kalman-type parameter estimation filter is used to update the ionosphere map as new TEC observations become available. The TEC value at each of 642 vertices is updated once every hour if data near the vertex is available. Otherwise, the vertex value is smoothly interpolated in time between updated values. Kalman filter updating and the use of local grid-based interpolation enable accurate monitoring of sub-hourly changes in the ionosphere over both regional and global scales.

The accuracy of the maps has been assessed by direct comparisons to independent vertical TEC measurements derived from the dual-frequency altimeter on the TOPEX satellite. The TOPEX comparisons indicate that the maps are generally accurate to 5 TECU (1 TECU = 10^{16} el/m^2) in the mid-latitudes and 5-10 TECU in the more variable equatorial region.

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